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[54] **MUFFLER/EXHAUST EXTRACTOR AND METHOD**

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[51] **Int. Cl.**[6] **F01N 1/08**

[52] **U.S. Cl.** **181/264**; 181/280; 181/258

[58] **Field of Search** 181/252, 255, 181/256, 258, 264, 268, 269, 272, 275, 279, 280, 282

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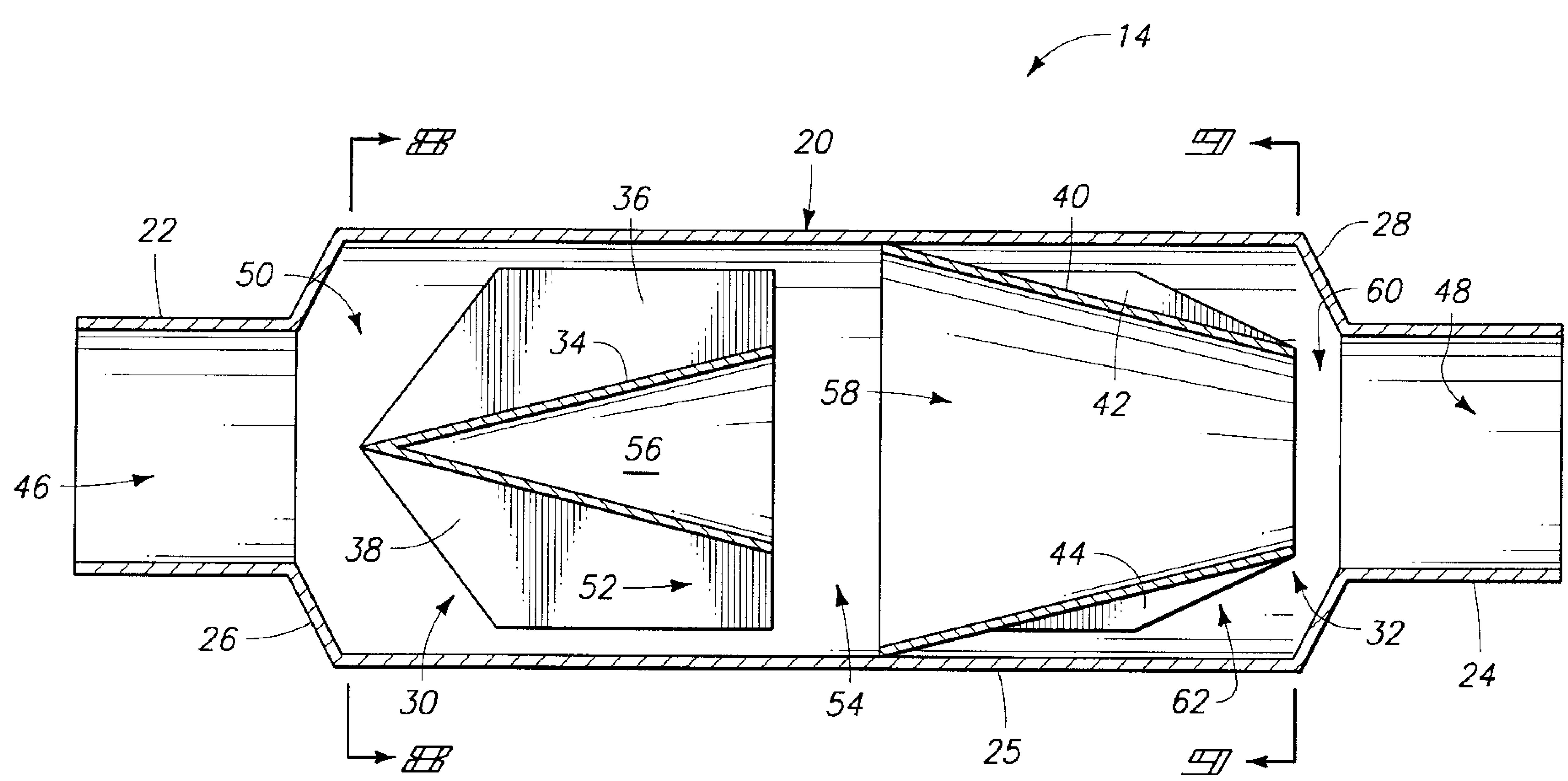
Primary Examiner—Khanh Dang
Attorney, Agent, or Firm—Wells, St. John, Roberts, Gregory & Matkin, P.S.

[57] **ABSTRACT**

An exhaust conditioning device, comprising a housing having an entrance duct, an exit duct, and a hollow interior defined within the housing between the entrance duct and the exit duct; a conical baffle carried coaxially within the housing downstream of the entrance duct and configured to form a generally outwardly extending compression chamber therebetween; and a frustoconical baffle carried coaxially within the housing downstream of the conical baffle and upstream of the exit duct and configured to form a generally inwardly extending compression chamber; wherein the conical baffle cooperates with the housing to form a conical vacuum chamber and the frustoconical baffle cooperates with the housing to form a substantially annular vacuum chamber, downstream of the conical vacuum chamber. In one form, the exhaust conditioning device comprises an exhaust muffler. Additionally, a method is disclosed.

19 Claims, 7 Drawing Sheets



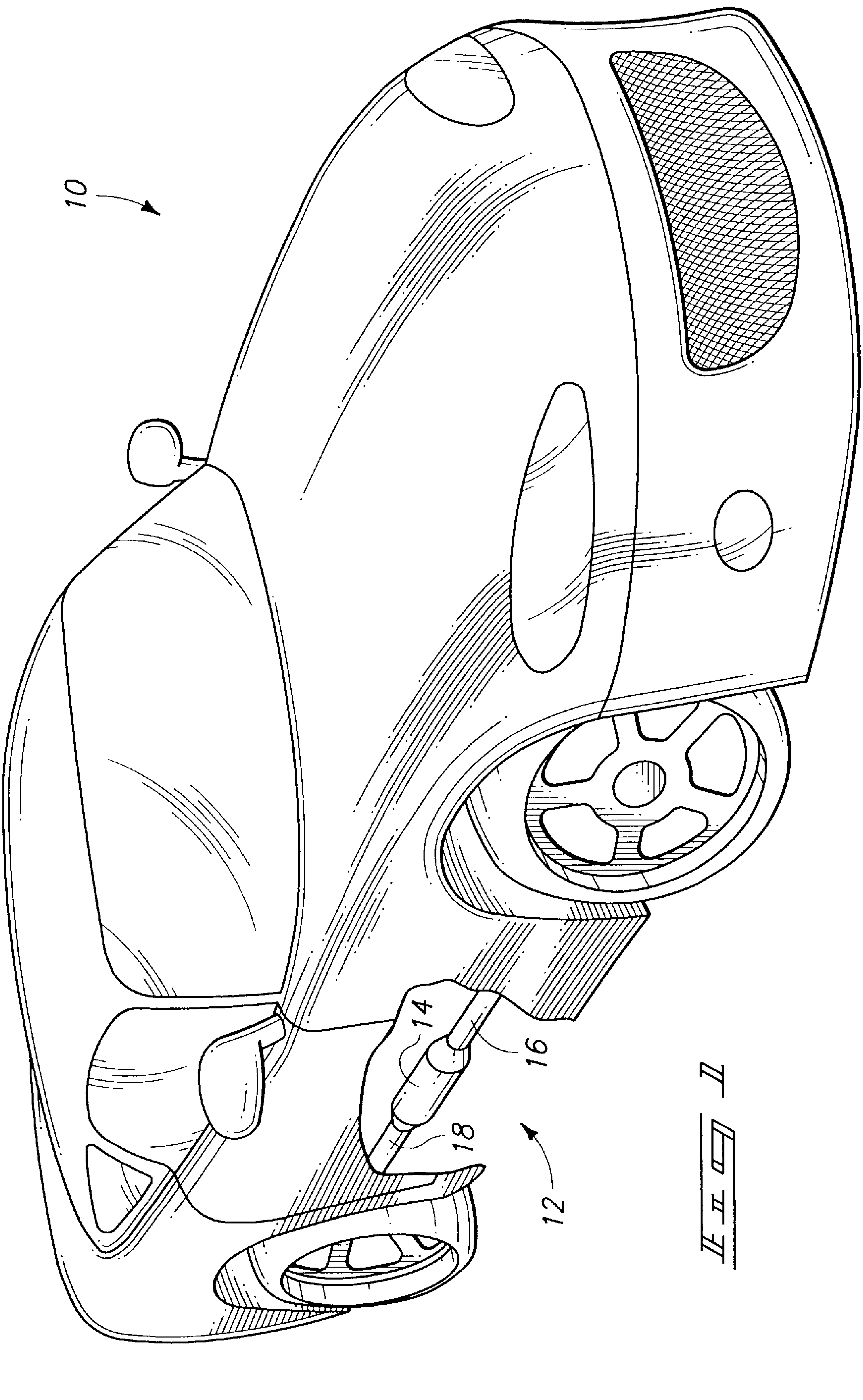


FIG. 1

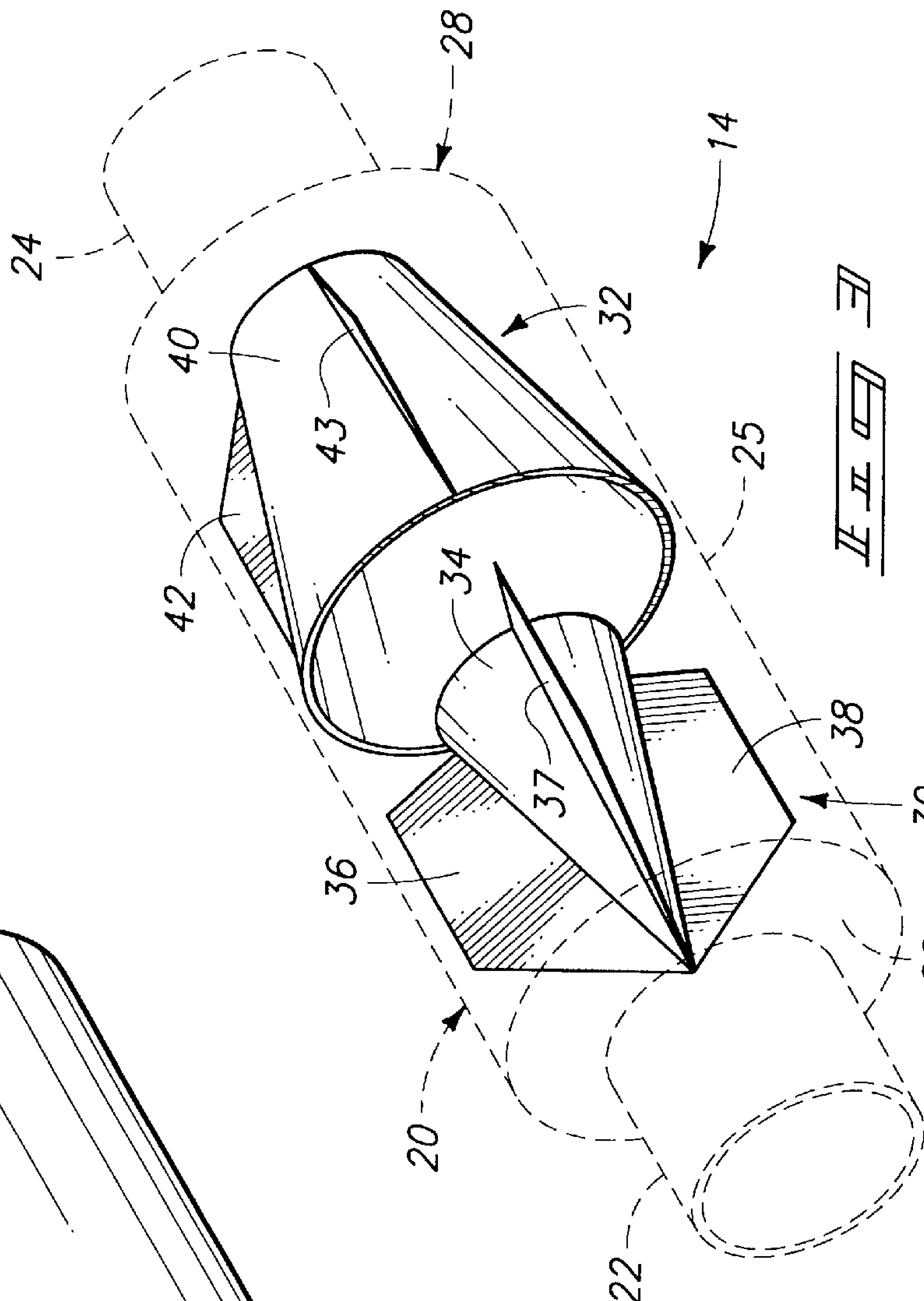


FIG. 3

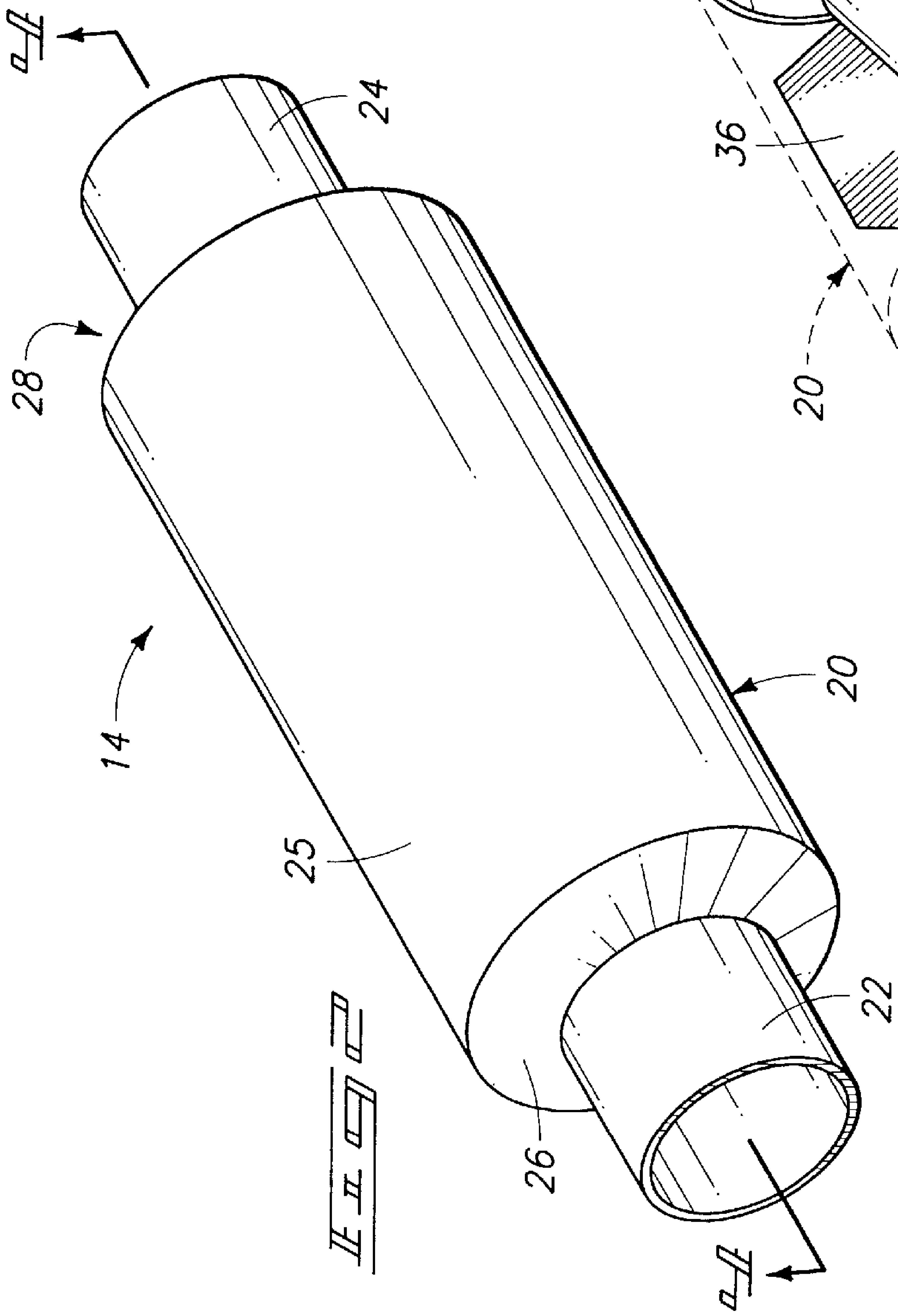


FIG. 2

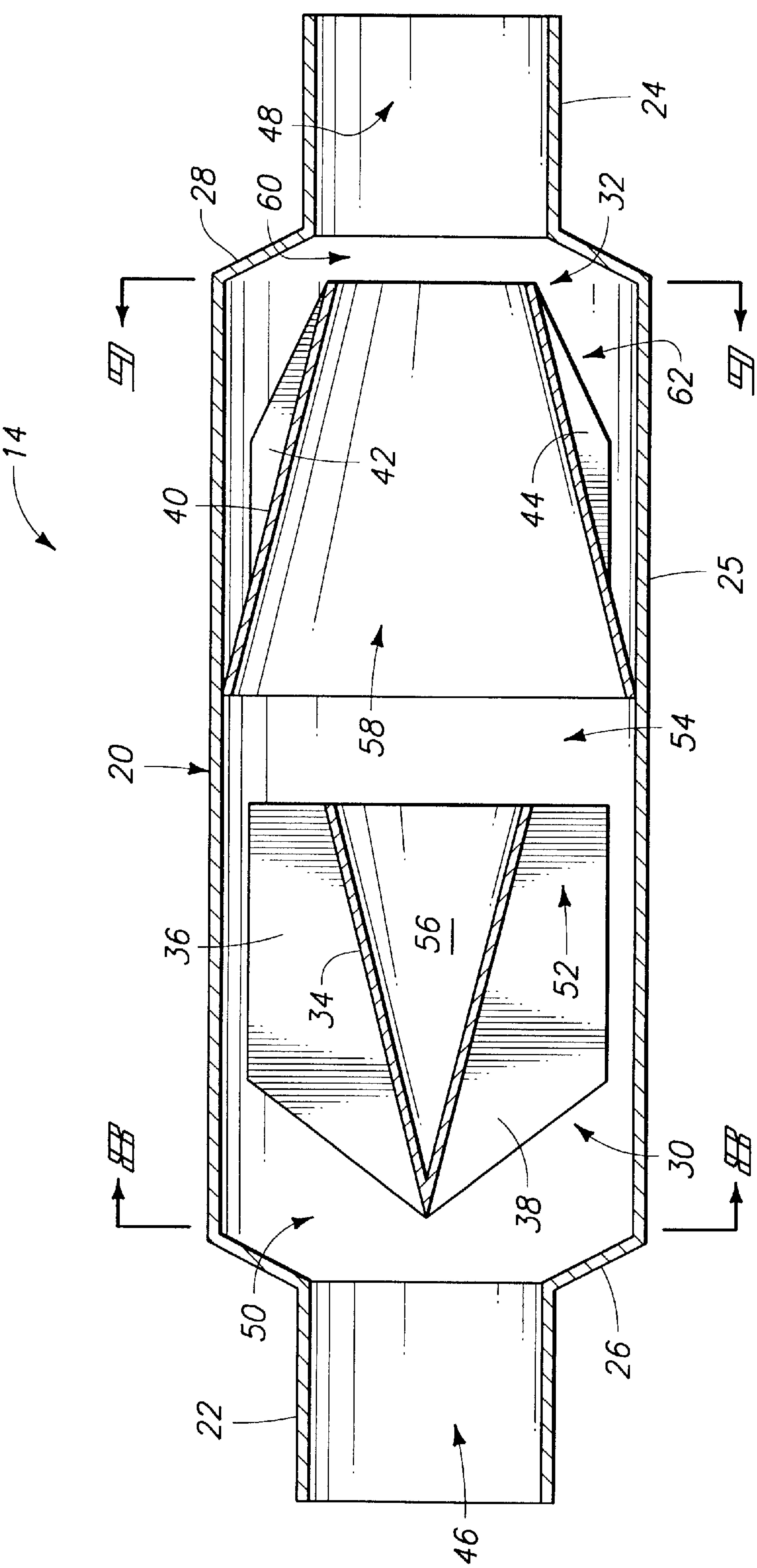


Fig. 4

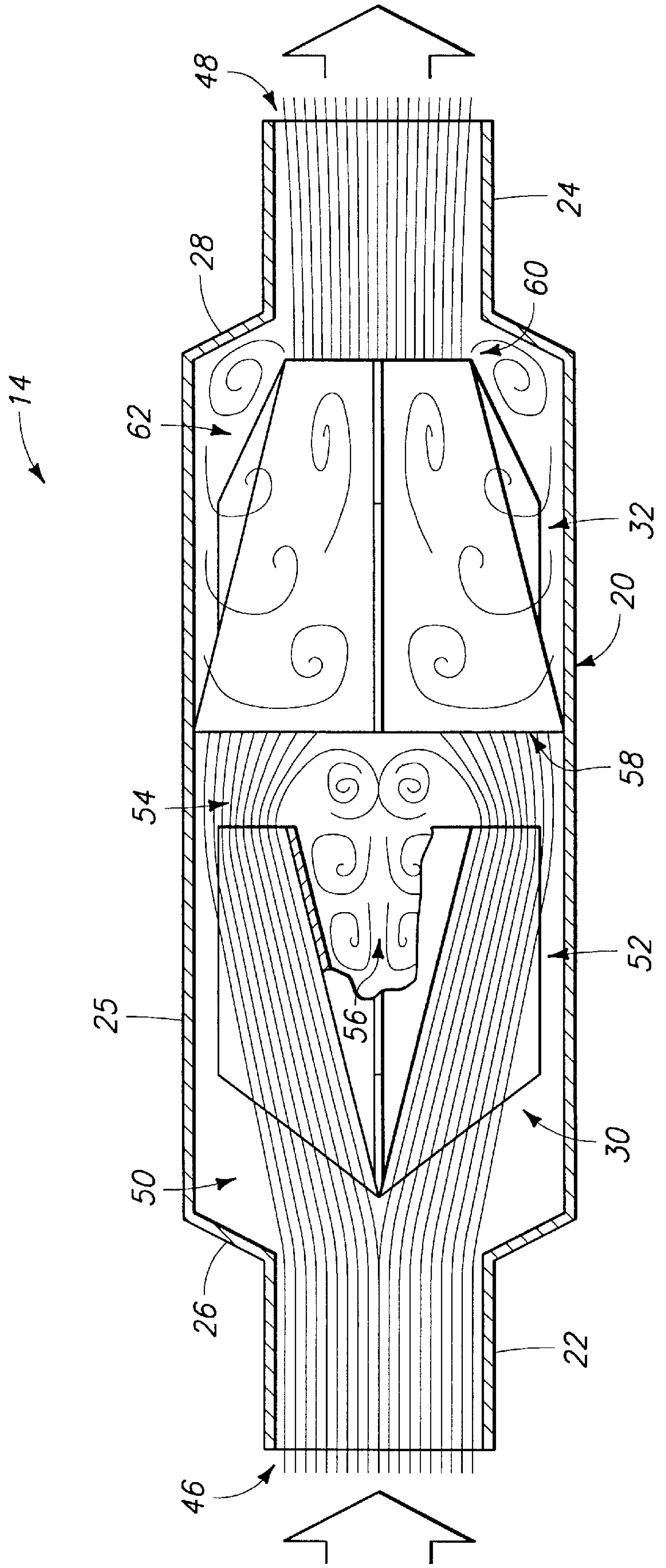


Fig 5

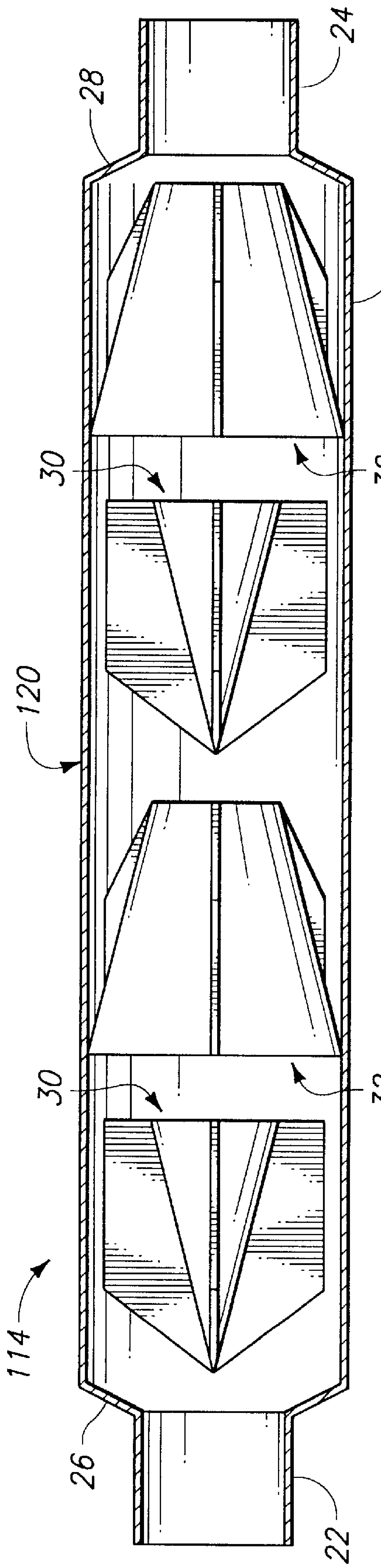

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FIG. 6

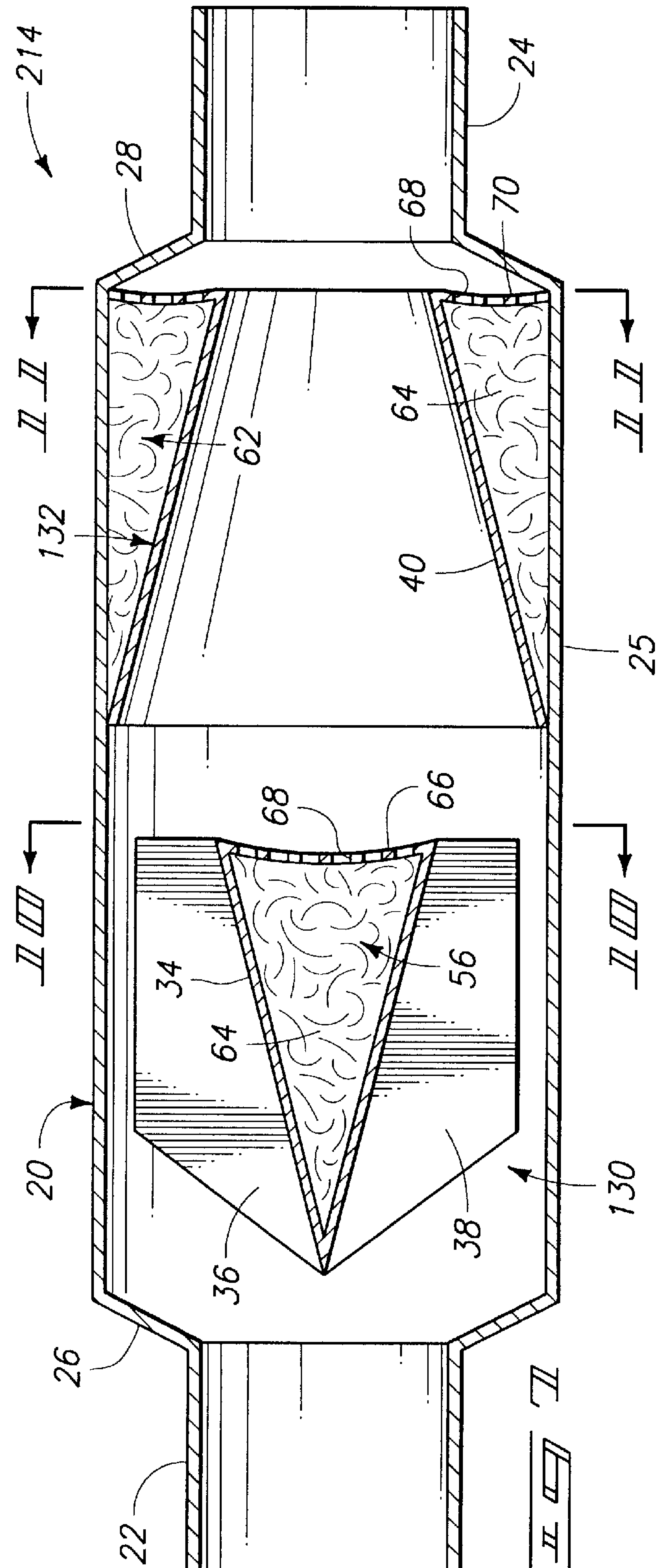
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FIG. 7

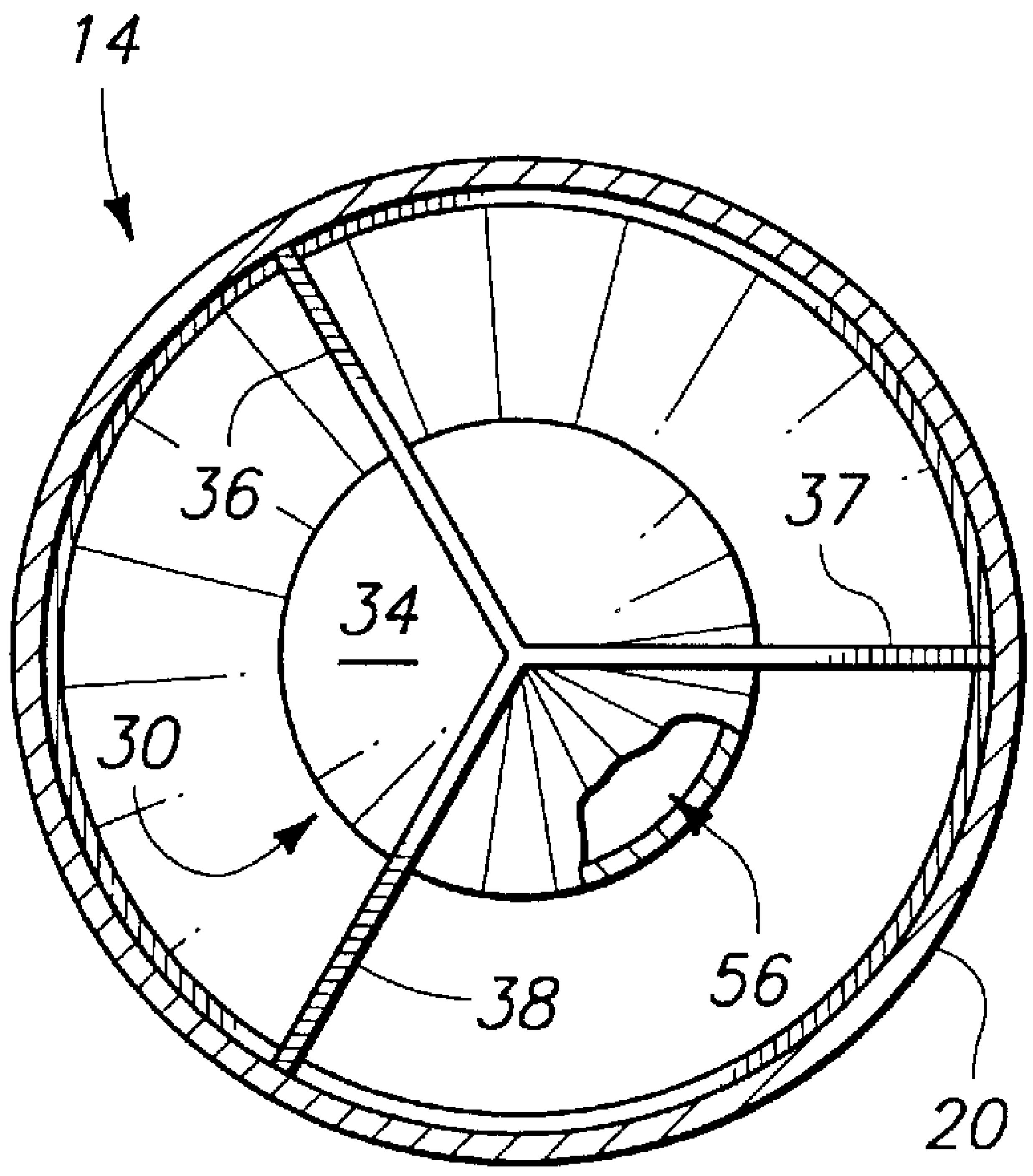

Fig. 8

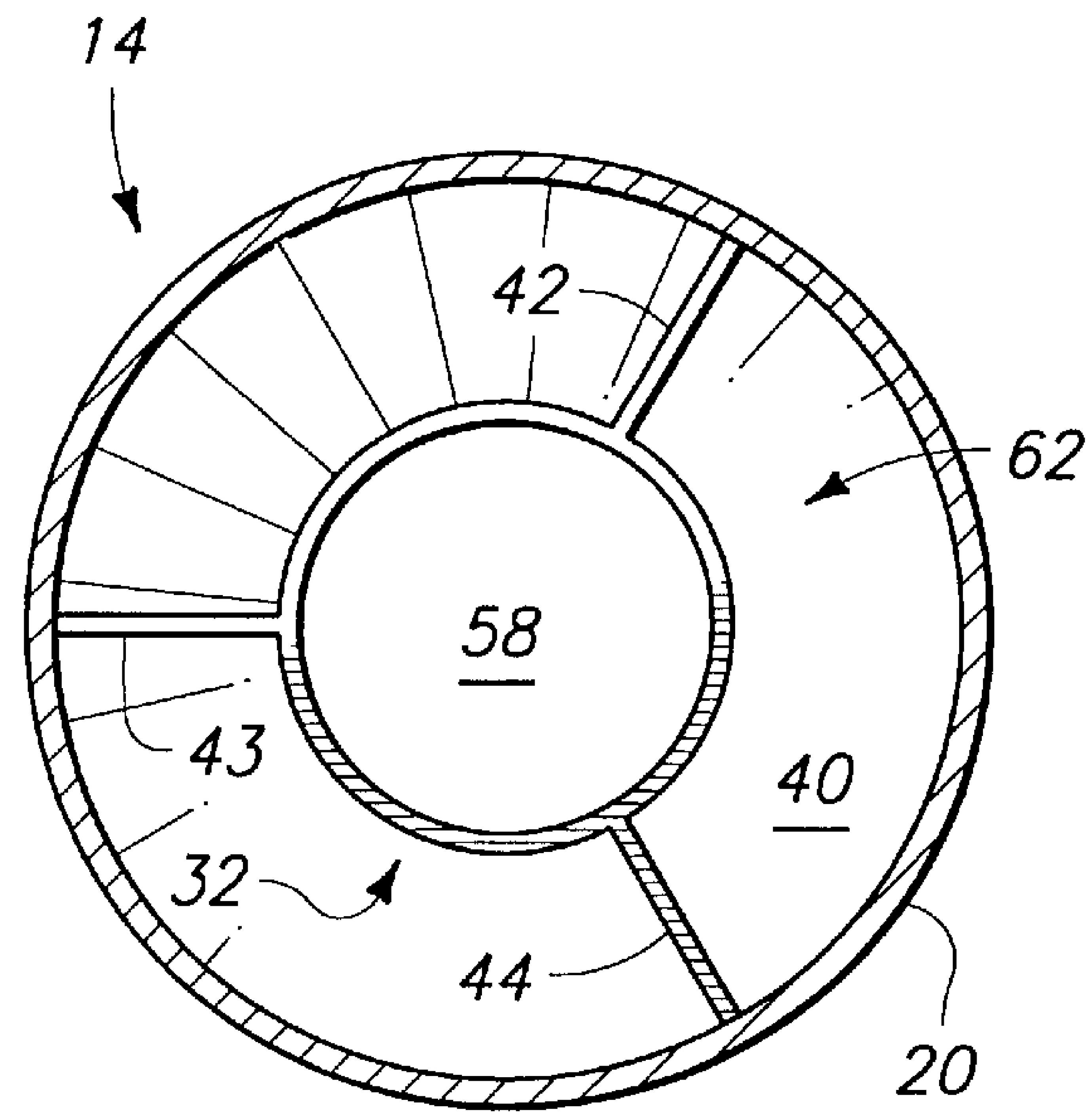

Fig. 9

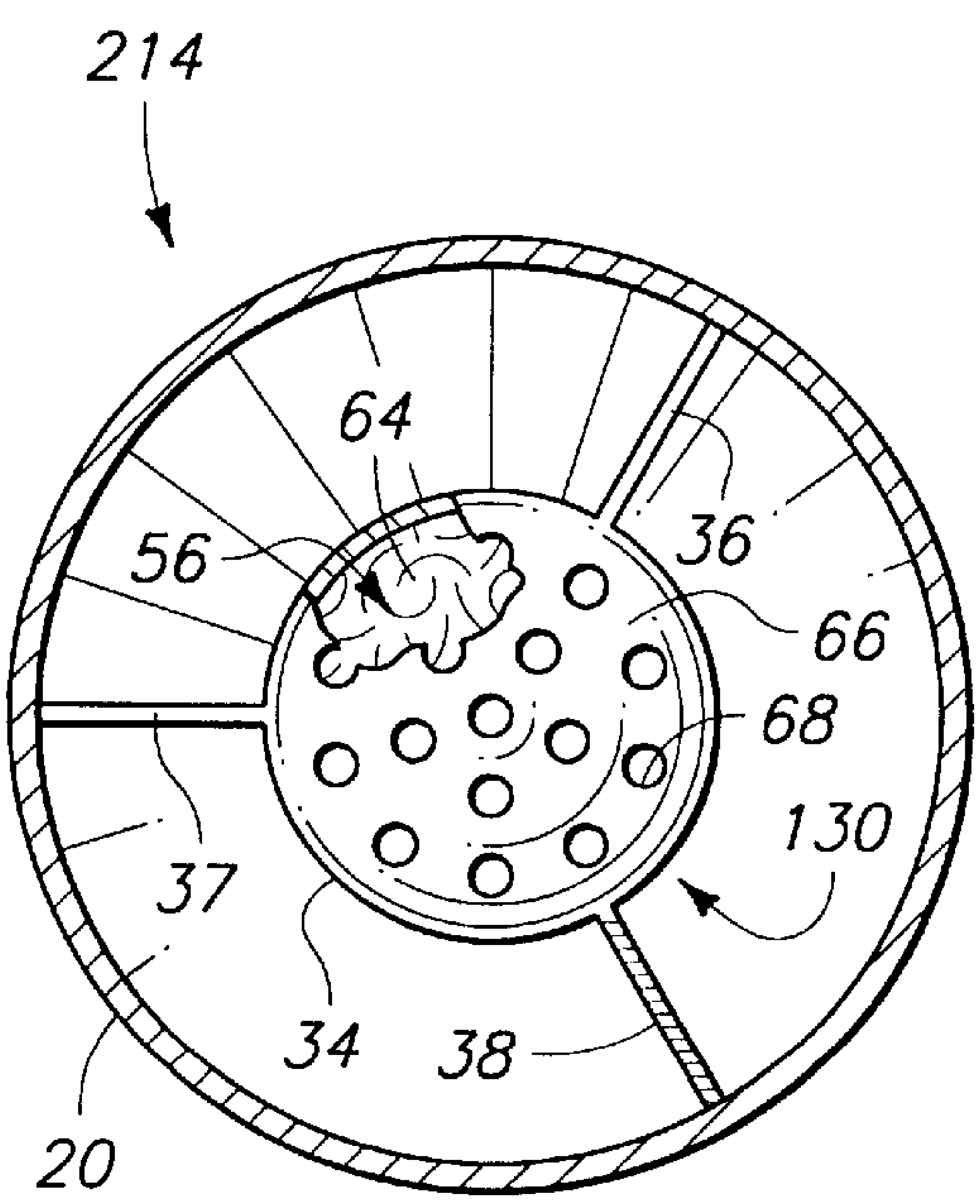

Fig. 10

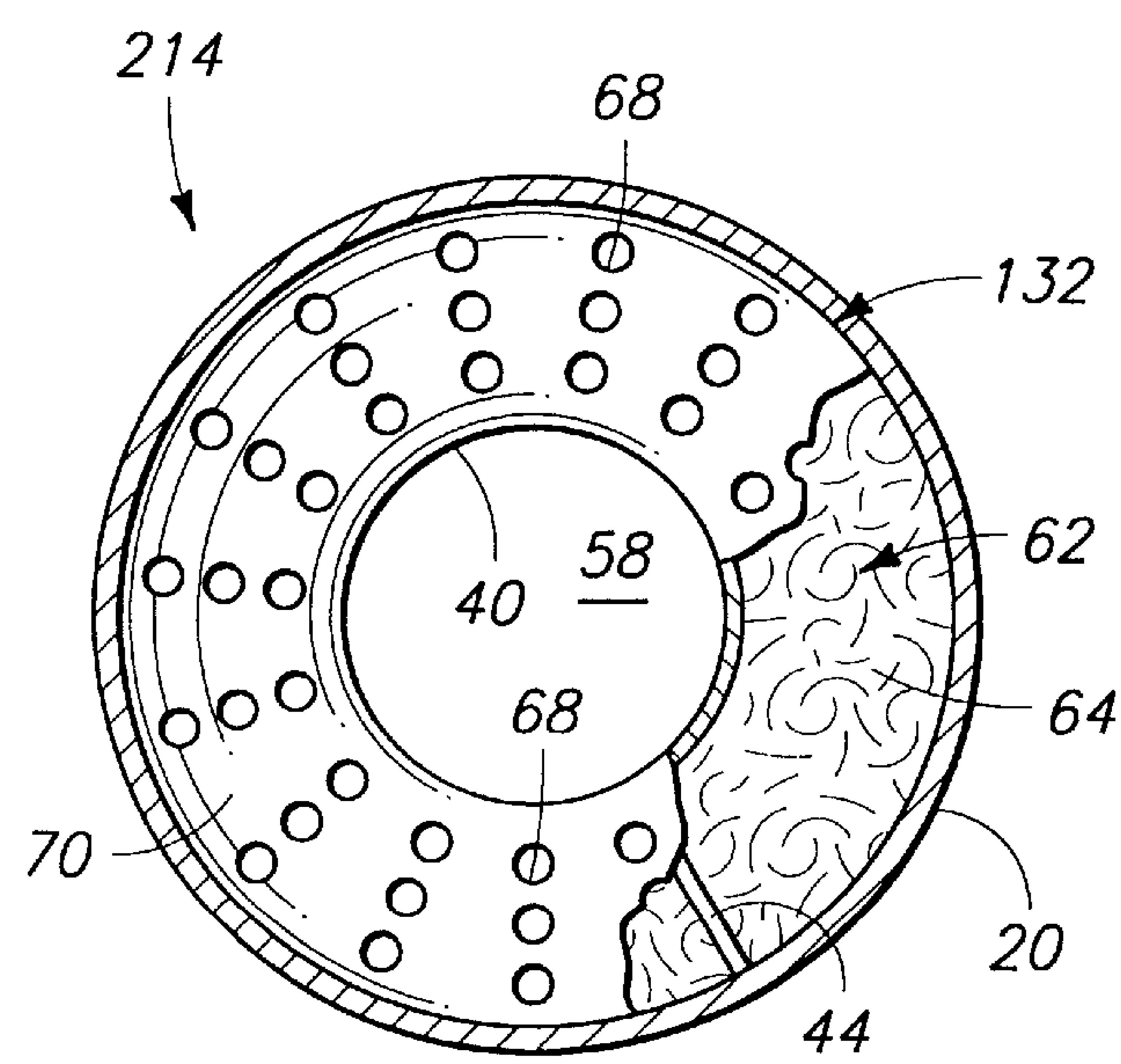

Fig. 11

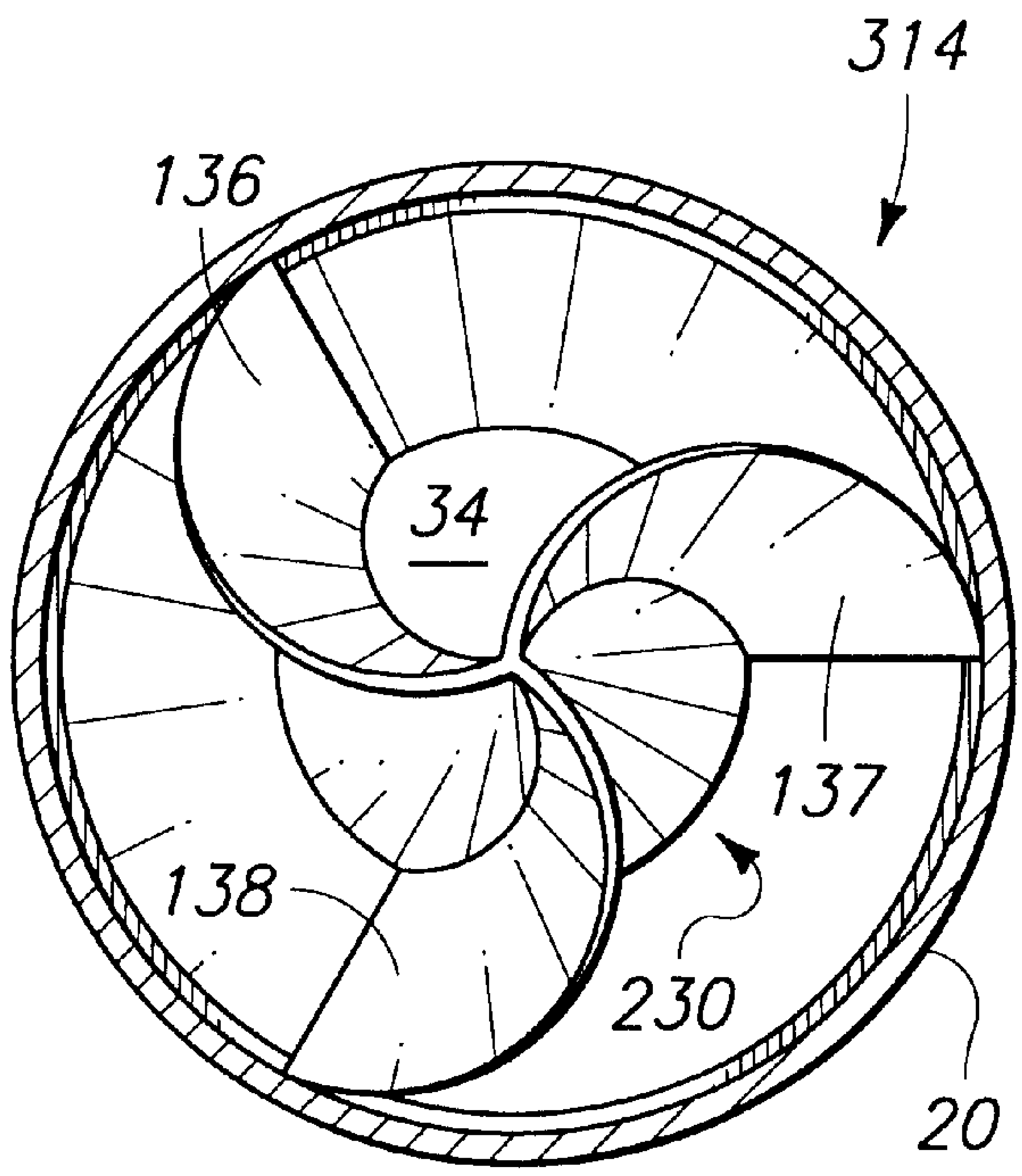

Fig 12

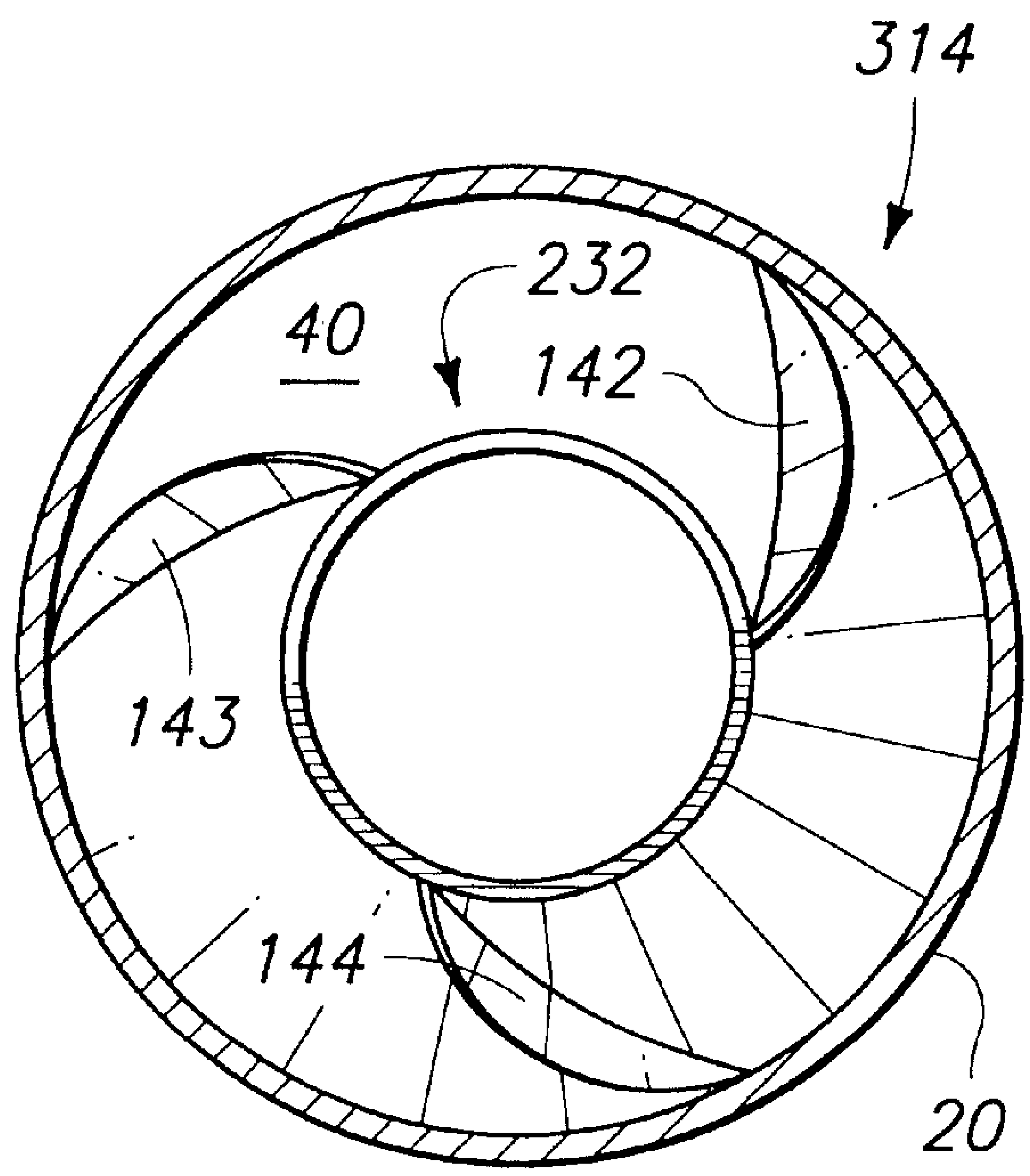

Fig 13

MUFFLER/EXHAUST EXTRACTOR AND METHOD

TECHNICAL FIELD

This invention relates to a device and method for facilitating exhaust action and noise abatement of high velocity air or gas exhaust flow, and more particularly to a muffler for use with internal combustion engines.

BACKGROUND OF THE INVENTION

Various engines including internal combustion engines and turbine engines produce exhaust gases containing undesirable levels of noise. The problem of muffling and evacuating such exhaust gases is well known. Automobiles utilize exhaust systems that couple with an internal combustion engine and contain combinations of headers, collectors and mufflers. One type of muffler contains a plurality of chambers that are formed within a casing or housing by a plurality of baffles. The baffles are arranged to form a circuitous path from an inlet end of the housing to an exit end of the housing. Typically, sound-absorbing material such as stainless steel wool is also provided in portions of the housing to further reduce high frequency components of noise.

Another type of exhaust system component that facilitates evacuation of exhaust gases is disclosed in U.S. Pat. No. 5,282,361 to Sung. More particularly, a device is provided for facilitating exhaust action of an internal combustion engine. Induction and acceleration of air resistance is imparted from forward movement of a vehicle via a guided flow depression device and a forced exhaust device. However, little or no muffling is provided by the device.

Therefore, there is a need to provide a device and method that muffles exhaust gas noise. Furthermore, there is a need for a device and method that enhances evacuation of exhaust gases through an exhaust system. Even furthermore, there is a need to provide such device and method so as to improve engine operating efficiency by reducing back pressure at engine exhaust ports.

The present invention arose from an effort to develop a muffler that reduces exhaust system noise, reduces back pressure at the engine intake valves, imparts smoother exhaust flow, and improves exhaust evacuation from an engine and exhaust system. Such muffler provides these features in a manner that is relatively low cost, is relatively lightweight, has operating characteristics that can be easily tuned to a particular engine and exhaust system, and is resistant to rust and corrosion.

SUMMARY OF THE INVENTION

The present invention relates to a muffler and exhaust gas evacuator.

According to one aspect of the invention, a muffler includes an outer casing having an elongate configuration, a hollow interior, and an inlet end and an outlet end. End caps are mounted one at the inlet end and the other at the outlet end of the outer casing. Entrance and exit ducts are connected to and communicate respectively with the end caps at the inlet end and the outlet end of the outer casing. A conical diverging flow deflector is supported coaxially within the hollow interior of the outer casing adjacent the entrance duct. A funnel-shaped converging flow deflector is supported coaxially within the hollow interior of the outer casing, downstream of the conical deflector. The conical deflector forms a conical vacuum chamber, and the funnel-shaped deflector cooperates with the casing to form an annular-shaped vacuum chamber.

According to another aspect of the invention, an exhaust conditioning device includes a housing having an entrance duct, an exit duct, and a hollow interior defined within the housing between the entrance duct and the exit duct. A conical baffle is carried coaxially within the housing downstream of the entrance duct and is configured to form a generally outwardly extending compression chamber therebetween. A frustoconical baffle is carried coaxially within the housing downstream of the conical baffle and upstream of the exit duct. The frustoconical baffle is configured to form a generally inwardly extending compression chamber. The conical baffle cooperates with the housing to form a conical vacuum chamber and the frustoconical baffle cooperates with the housing to form a substantially annular vacuum chamber, downstream of the conical vacuum chamber.

According to yet another aspect of the invention, a method for conditioning exhaust of an internal combustion engine comprises: delivering exhaust gases from an internal combustion engine into a muffler housing containing a hollow interior; accelerating and compressing the exhaust gases within the housing by passing the exhaust gases through a generally outwardly extending compression chamber; dampening pressure variations within the exhaust gases by delivering the compressed exhaust gases adjacent a low pressure chamber; compressing and accelerating the exhaust gases within the housing by diverting the exhaust gases in a generally inwardly extending direction within a compression chamber; and removing the exhaust gases from the housing.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the invention are described below with reference to the following accompanying drawings.

FIG. **1** is a perspective view of an automobile having an internal combustion engine with an exhaust system containing a preferred embodiment muffler according to one aspect of the invention;

FIG. **2** is a perspective view illustrating the muffler depicted in FIG. **1**;

FIG. **3** is a partial phantom view illustrating the internal baffles provided within the muffler of FIGS. **1** and **2**;

FIG. **4** is a longitudinal cross-sectional view taken along line **4**—**4** of FIG. **2** illustrating construction features within the muffler;

FIG. **5** is a diagrammatic illustration corresponding with the cross-sectional view depicted in FIG. **4**, but showing fluid flow paths extending within the muffler;

FIG. **6** is a longitudinal cross-sectional view similar to that depicted in FIG. **4**, but illustrating an alternative embodiment of the invention containing a serial array of the pair of baffles utilized in the embodiment depicted in FIGS. **1**–**5**;

FIG. **7** is a longitudinal cross-sectional view similar to that depicted in FIG. **4**, but illustrating another alternative embodiment of the invention that contains sound-absorbing material;

FIG. **8** is a cross-sectional view taken along line **8**—**8** of FIG. **4**;

FIG. **9** is a cross-sectional view taken along line **9**—**9** of FIG. **4**;

FIG. **10** is a cross-sectional view taken along line **10**—**10** of FIG. **7**;

FIG. **11** is a cross-sectional view taken along line **11**—**11** of FIG. **7**;

FIG. **12** is a cross-sectional view of even another alternative embodiment of the invention that contains helically shaped support fins taken at a location corresponding to the view depicted in FIG. **8**; and

FIG. **13** is a cross-sectional view of the alternative embodiment depicted in FIG. **12**, but taken at a location corresponding to the view depicted in FIG. **9**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

This disclosure of the invention is submitted in furtherance of the constitutional purposes of the U.S. Patent Laws "to promote the progress of science and useful arts" (Article 1, Section 8).

One problem encountered with engines and exhaust systems on vehicles results from cam shaft overlap. During cam shaft overlap, the exhaust valve just starts to close as the intake valve just starts to open. Therefore, both valves are open at the same time for a brief instant. On stock exhaust systems found on many vehicles today, there exists so much back pressure at the exhaust port that, when the intake valve opens, burnt portions of fuel mixture get pushed back into the intake side of the motor. This occurrence creates an excessive amount of internal crankcase pressure which causes problems with engine seals, and results in inefficiencies by limiting air/fuel mixture that is entering the combustion chamber. According to innovative aspects of this invention, a muffler is utilized to create a vacuum, or relatively low pressure region, at selected points within the muffler. Such vacuum helps pull air/fuel mixture into an engine's combustion chamber, and also evacuates the chamber after firing of combustion gases, making the engine more efficient and saving the consumer fuel so as to increase mileage and decrease wear and tear on an engine.

According to the embodiments and implementation of this invention, such muffler construction saves wear and tear on an engine. Furthermore, by more fully evacuating the chambers on an engine, engine temperature is also decreased at the head, which increases the reliability of the engine. Accordingly, not as much heat will be present at the exhaust manifolds where heat might otherwise cause breakage or leakage around the heads. Accordingly, longevity is added to the heads and exhaust system on an engine. Furthermore, an engine will not be required to work as hard in order to evacuate a combustion chamber. Therefore, a consumer will not have to push on the engine throttle as much in order to achieve the same operating speed on a vehicle, therefore saving fuel consumption and adding to the vehicle's mileage capabilities for a given amount of fuel. Even furthermore, it has been found that the maintenance of a certain amount of heat at the manifolds enables the realization of a much more efficient burn out of the combustion chamber, reducing the amount of emissions produced therefrom.

A preferred embodiment of the invention is shown on an automobile **10** as a component of an exhaust system **12** and is embodied as a muffler generally designated with reference numeral "**14**" in FIG. **1**. Exhaust system **12** is illustrated as an inlet pipe **16**, muffler **14**, and an outlet pipe **18**. However, it is understood that inlet pipe **16** is fluid coupled with the exhaust valves of an internal combustion engine (not shown) via a pair of exhaust manifolds, headers, header pipes, a collector, and a catalytic converter.

According to one construction, inlet pipe **16** and outlet pipe **18** are welded directly onto opposite ends of muffler **14**. According to another construction, muffler **14** includes an inlet duct and an outlet duct that each form short tubular

segments extending from opposite ends of muffler **14**. Such inlet duct and outlet duct are crimped so as to enable insertion within an end of inlet pipe **16** and outlet pipe **18**, respectively. Typically, the inlet duct and the outlet duct are each circumferentially welded to inlet pipe **16** and outlet pipe **18**, respectively.

FIG. **2** illustrates in enlarged perspective view the construction of muffler **14**. As shown in FIG. **2**, muffler **14** is embodied with an inlet duct **22** and an outlet duct **24** formed at opposite ends of a cylindrical housing **20**. A pair of end caps **26** and **28** are fitted to opposite ends of a tubular body **25** so as to form cylindrical housing **20**. End cap **26** is also fitted to inlet duct **22**, whereas end cap **28** is fitted to outlet duct **24**.

According to the embodiment depicted in FIG. **2**, housing **20** is formed in the shape of an elongated cylinder, with end caps **26** and **28** each being mated to opposite ends of tubular body **25**. End caps **26** and **28** are each formed in the shape of a funnel, or shallow frustoconical tube. Each end cap **26** and **28** has a radial-inner circumferential edge the forms a radial-inner aperture along which one of ducts **22** and **24** is mated. Each one of end caps **26** and **28** has a radial outer circumferential edge along which such end cap is mated with housing **20**.

According to one construction, end caps **26** and **28** are welded along a radial outer circumferential edge to respective cylindrical ends of tubular body **25** via a circumferential weld. Similarly, inlet duct **22** and outlet duct **24** are welded along such radial-inner circumferential edge to end caps **26** and **28**, respectively. In this manner, end caps **26** and **28**, ducts **22** and **24**, and tubular body **25** cooperate to form housing **20**.

Optionally, end caps **26** and **28** can be configured to form a flange along a radial outer edge and a flange along a radial inner edge such that each end cap is inserted within a circumferential opening at an associated end of tubular body **25**. Accordingly, each end cap is then circumferentially welded to a respective end of tubular body **25** so as to join together the flange and body **20**. Similarly, a respective one of ducts **22** and **24** is circumferentially welded to a similar flange on an associated radial inner edge of end cap **26** or **28**.

Tubular body **25** and end caps **26** and **28** cooperate in assembly to form a torpedo-shaped chamber within housing **20**. Accordingly, housing **20** has a hollow interior for muffling and evacuating exhaust gases received from an internal combustion engine via an exhaust system. It is understood that tubular body **25** and end caps **26** and **28**, of housing **20**, can be configured so as to impart a modified geometry to muffler **14**. For example, housing **20** can be lengthened so as to lengthen individual chambers that are defined within such housing. Alternatively, housing **20** can be lengthened to provide for the incorporation of additional baffles, or flow deflectors, within such housing, as shown below with reference to FIG. **6**. Even further, housing **20** can be configured to have a non-cylindrical cross-section. For example, housing **20** can be constructed with an elliptical cross-section. Similarly, end caps **26** and **28** can be configured to have a hemispherical or flat shape.

FIG. **3** depicts the internal structural features of muffler **14** with housing **20** shown in phantom. More particularly, FIG. **3** depicts the internal structural features of muffler **14**, with tubular body **25**, end caps **26** and **28**, and ducts **22** and **24** shown in phantom to facilitate viewing. A pair of fluid flow deflecting baffle assemblies **30** and **32** are supported within housing **20** where they are welded into place.

Baffle assembly **30** comprises a cone-shaped baffle that is welded to an inner surface of tubular body **25**, adjacent to inlet duct **22**, and between inlet duct **22** and outlet duct **24**.

Baffle assembly **32** is similarly supported within housing **20** where it is welded in place downstream of baffle assembly **30**, and adjacent to outlet duct **24**.

As shown in FIG. **3**, the relative positioning and cooperation of baffle assemblies **30** and **32** within housing **20** generates a desired level of noise abatement and exhaust gas evacuation. Such benefits are realized by implementation of this invention as exhaust gases travel over baffle assemblies **30** and **32**. More particularly, exhaust gases are delivered to muffler **12** via exhaust duct **20** where they pass over baffle assembly **30**, and particularly over conical baffle **34** of assembly **30**. Subsequently, such exhaust gases expand as they pass downstream of conical baffle **34**, and enter a funnel-shaped frustoconical baffle **40** of baffle assembly **32**. Such gases are compressed as they pass within frustoconical baffle **40**, prior to being expanded and ejected from housing **20** via outlet duct **24**.

Baffle assemblies **30** and **32** cooperate in assembly to impart compression and expansion to exhaust gases as such gases travel through housing **20**, between inlet duct **22** and outlet duct **24**. Such compression and expansion imparts noise cancellation, particularly to high frequency components, which significantly mitigates the transmission of noise therethrough. Additionally, baffle assemblies **30** and **32** each cooperate with housing **20** to generate a venturi effect immediately downstream of cone baffle **34** and frustoconical baffle **40**, respectively, to produce a low pressure, or vacuum, region there adjacent.

Baffle assemblies **30** and **32** are each supported coaxially within cylindrical housing **20**, in spaced-apart relation. Conical baffle **34** on assembly **30** forms a hollow interior on a downstream side, or inside, of conical baffle **34**. Exhaust gases are compressed outwardly along the outside of conical baffle **34** and form a vacuum within the inside, or back side, of cone **34**. Such vacuum is generated via a venturi effect that generates suction on the inside of cone **34**. In this manner, it is presently believed, that a negative pressure area, relative to atmosphere, is created inside of cone **34** which generates a relative vacuum. Such vacuum facilitates the pulling of exhaust gases through housing **20**, in a downstream direction around baffle assembly **30** and into baffle assembly **32**.

Frustoconical baffle **40** of baffle assembly **32**, which is positioned downstream of baffle assembly **30**, receives and directs exhaust gases. More particularly, baffle **40** compresses and converges exhaust gases that are received from baffle assembly **30**. Such exhaust gases are compressed and converged inwardly along a central axis as they pass through frustoconical baffle **40**. An annular region extending between conical baffle **40** and housing **20** is formed around the exit of frustoconical baffle **40**, which creates a segmented second negative (low) pressure, or vacuum chamber, there along. It is presently believed that such vacuum chamber is partially evacuated via a venturi effect that generates suction on the inside of a segmented annular region defined between frustoconical baffle **40** and an interior of housing **25**.

Exhaust gases passing through frustoconical baffle **40** facilitate generation of a vacuum thereabout which further serves to pull exhaust gases through muffler **20** and out of outlet duct **24**. Details of such vacuum or negative pressure chambers will be discussed below in greater detail with reference to FIGS. **4** and **5**. The presence of such relatively low pressure regions, generated by baffles **34** and **40**, is believed to impart a dampening effect to pressure pulses that might otherwise reflect and travel in an upstream direction through an exhaust system. Hence, the return of high pressure pulses to a header and manifold can be mitigated by the presence of such low pressure regions within a muffler.

According to the construction depicted in FIGS. **2** and **3**, the components of cylindrical housing **20** are constructed from 14-gauge aluminized, or aluminum impregnated, mild steel. Namely, tubular body **25**, inlet duct **22**, outlet duct **24**, and end caps **26** and **28** are each constructed from such aluminized mild steel. Additionally, baffle assemblies **30** and **32** are also formed from such 14-gauge aluminized mild steel. Alternatively, such components can be formed from mild steel where corrosion is not a concern. Even furthermore, such components can be formed from any of a number of various grades of stainless steel where cost is of less concern and the prevention of corrosion of high concern.

As illustrated in FIG. **3**, baffle assembly **30** comprises a centrally located conical baffle **34** that is supported coaxially within the inner surface of housing **20** via a plurality of radially-extending fins **36–38**. Although three equally spaced-apart and radially-extending fins **36–38** are depicted supporting conical baffle **34**, it is understood that any of a number of fins can be utilized to support conical baffle **34** in coaxial relation within housing **20**. Even furthermore, it is also understood that such fins **36–38** can be configured in any of a number of arrangements within housing **20** so as to support conical baffle **34** therein.

For example, one alternative embodiment is depicted in FIGS. **12–13** wherein such fins are imparted with a helical configuration so as to swirl exhaust gases within housing **20**, and along conical baffle **34** (as well as along frustoconical baffle **40**). Further details of such embodiment will be described below with reference to FIGS. **12–13**.

Also as shown in FIG. **3**, baffle assembly **32** is formed from frustoconical baffle **40** which is shaped as a funnel, having a plurality of radially outwardly extending support fins **42–44**. Fins **42–44** each extend radially outwardly from baffle **40** and are axially aligned to be parallel with the longitudinal axis of housing **20**. Furthermore, fins **42–44** are equally spaced-apart about the outer circumference of frustoconical baffle **40**. Fins **42–44** are welded to a radial outer surface of frustoconical baffle **40**, then tack welded to an inner diameter surface of tubular body **25** of housing **20**.

According to one construction, baffle assembly **30** is formed by edge welding each of fins **36–38** along an outer surface of conical baffle **34**, then inserting such subassembly within housing **20** and tack welding the radial outer edges of fins **36–38** to an inner diameter of tubular member **25**. Following such insertion and welding, baffle assembly **32** is similarly inserted and welded along fins **42–44**, after which end caps **26** and **28** and outlet ducts **22** and **24** are welded to opposite ends of tubular body **25**, respectively.

FIG. **4** illustrates the structural features of muffler **14** as taken in cross-sectional view along line **4**—**4** of FIG. **2**. Such view has been taken in a directional parallel to the planer orientation of fins **38** and **44**, as shown in FIG. **3**. Accordingly, conical baffle **34** and frustoconical baffle **40** are shown in centerline sectional view, within housing **20** which is also shown in centerline sectional view. More particularly, the orientation and spacing of baffle assemblies **30** and **32** can be clearly seen within housing **20**. FIGS. **8** and **9** further depict the structural features of muffler **14**.

A muffler chamber is formed internally of housing **20** via cooperation of tubular member **25**, end caps **26** and **28**, as well as inlet duct **22** and outlet duct **24**. An inlet port **46** is formed by inlet duct **26** through which exhaust gases enter muffler **20**. It is understood that an inlet pipe of an exhaust system is welded to inlet duct **22**, and an outlet pipe of an exhaust system is welded to outlet duct **24**. In this manner, exhaust gases enter muffler **14** via inlet duct **22** where they expand within an expansion chamber **50** provided upstream of baffle assembly **30**.

Exhaust gases then pass along conical baffle **34**, between fins **36–38**, where gas flow is diverted from along the axis of housing **20** in an outward manner. As a result, exhaust gases are compressed within a compression chamber **52** formed in three segments between fins **36–38**. A second expansion chamber **54** is formed downstream of baffle assembly **30** where such compressed and accelerated exhaust gases are expanded. Exhaust gases exiting the downstream end of conical baffle **34** are accelerated to a high speed which imparts a venturi effect such that a vacuum chamber **56**, formed within conical baffle **34**, generates a vacuum source. Such vacuum source has a pressure below the adjacent exhaust gas pressures present in compression chamber **52**. According to one implementation, such pressure is below atmospheric pressure.

Exhaust gases then travel from expansion chamber **54** where they enter a second compression chamber **58** formed within frustoconical baffle **40**. Such exhaust gases are directed in an opposite radial direction than they were by baffle assembly **30**; namely, such gases are compressed radially inwardly towards a central axial location within housing **20** until they exit from the downstream end of conical baffle **40**. Another expansion chamber **60** is formed immediately downstream of conical baffle **40** where such exhaust gases are ejected at relatively high velocity. A small amount of expansion occurs within expansion chamber **60** before exiting through outlet duct **24** via outlet port **48**. The passage of exhaust gases at high velocity through expansion chamber **60** generates a venturi effect adjacent an annular-shaped vacuum chamber **62** defined between frustoconical baffle **40** and the inner surface of housing **20**, and between fins **42–44**.

As best illustrated in FIG. **4**, conical baffle **34** cooperates with body **25** to form a flow-directing generally outwardly extending compression chamber **52**. Likewise, frustoconical baffle **40** forms a flow-directing generally inwardly extending compression chamber **58**.

According to one construction, the embodiment depicted in FIGS. **1–5** is manufactured from components made from 14-gauge aluminized, or aluminum-impregnated, mild steel. Such aluminized steel is resistant to acidics that are generated by a catalytic converter provided in an exhaust system upstream of the muffler **14**. Optionally, muffler **14** can be constructed from a stainless steel alloy. However, stainless steel tends to turn yellow when subjected to relatively high temperatures which aesthetically reduces the outward appearance of muffler **14**.

According to the construction depicted in FIGS. **4** and **5**, tubular body **25** is six inches in diameter and approximately 13.9 inches in length. End caps **26** and **28** are frustoconically shaped so as to have an unassembled height, extending along the central axis, of approximately one-half of an inch. Inlet duct **22** and outlet duct **24** are each formed from a three-inch diameter piece of cylindrical aluminized mild steel tubing.

Conical baffle **34**, of baffle assembly **30**, is configured with a three-inch diameter base and a six-inch length extending along the central axis. Individual fins **36–38** are sized to have a radial outermost edge dimension of four inches in length, along which such fins mate to the inner wall of tubular body **25**.

Frustoconical baffle **40**, of baffle assembly **32**, is configured with an upstream edge having a diameter of nearly six inches, and a downstream edge having a diameter of three inches. Accordingly, frustoconical baffle **40** is sized to have an axial length of 6.5 inches. Fins **42–44** are each sized so as to have a radial outermost edge length of four inches, along which such fins mate with an inner wall of tubular body **25**.

FIG. **8** is a vertical sectional view taken through muffler **14** along line **8—8** of FIG. **4** and illustrating the configuration of baffle assembly **30** within cylindrical housing **20**. The equally spaced radially-outwardly extending configuration for fins **36–38** can be readily seen. Furthermore, the coaxial alignment of conical baffle **34** within the cylindrical body of housing **20** is readily apparent. Accordingly, exhaust gases are delivered into housing **20** where they are diverted by conical baffle **34** in a circumferential and radially outwardly extending manner, causing such exhaust gases to compress and accelerate between conical baffle **34** and the inner wall of housing **20**.

FIG. **9** is a vertical sectional view taken along line **9—9** of FIG. **4** illustrating the coaxial positioning of baffle assembly **32** within the cylindrical body of housing **20**. As was the case with baffle assembly **30** depicted in FIG. **8**, baffle assembly **32** is also carried coaxially within the inner surface of housing **20** by fins **42–44**. Preferably, fins **42–44** in end-view are arrayed in alignment with fins **36–38** (of FIG. **8**). Optionally, fins **42–44** can be offset with fins **36–38**. Exhaust gases are accelerated by frustoconical baffle **40** where they exit at high velocity via a cylindrical aperture provided at a downstream end of compression chamber **58**. The region defined between frustoconical baffle **40** and an inner wall of housing **20** provides for an annular vacuum chamber **62** that is divided into three segments by fins **42–44**.

FIG. **5** is a diagrammatic vertical and partial centerline sectional view illustrating exhaust gas flow through muffler **14**. Baffle assembly **30** is shown in partial breakaway view and baffle assembly **32** is shown in full side view. More particularly, flow lines depicting the passage of exhaust gases through muffler **14** can be seen extending from inlet port **46** of inlet duct **22** to outlet port **48** of outlet duct **24**. Exhaust gases pass from inlet port **46** into expansion chamber **50** where such gases expand upon entering chamber **50**. The exhaust gases are then diverted radially outwardly by baffle assembly **30** and compressed within compression chamber **52** where they are accelerated.

Accelerated exhaust gases exit compression chamber **52** and move radially inwardly within expansion chamber **54**, causing a venturi effect that induces a negative pressure, or vacuum, within vacuum chamber **56**. Vacuum chamber **56** imparts further draw on exhaust gases in the region of expansion chamber **54** which functions to assist in drawing exhaust gases from expansion chamber **54**. Additionally, vacuum chamber **56** also functions to smooth out exhaust flow moving through muffler **14**, and dampens pulsatile flow, or pressure variations, occurring within the exhaust gas of muffler **14**. Accordingly, pressure pulses travelling within the exhaust gases of an exhaust system can be dampened via a muffler **14** of this invention.

Exhaust gases pass from expansion chamber **54** into compression chamber **58** where they are compressed and accelerated. Exhaust gases exit compression chamber **58** at a relatively high velocity and are ejected into expansion chamber **60**. Such relatively high-velocity gases exit through expansion chamber **60** and into outlet port **48**. The delivery of relatively high-velocity exhaust gases into expansion chamber **60** induces a low pressure region, or vacuum, in vacuum chamber **64**.

Vacuum chamber **64** is located between the outer surface of baffle assembly **32** and the inner surface of housing **20**. Such subdivided annular chamber **64** further facilitates the draw and passage of exhaust gases into expansion chamber **60**, and serves to dampen out any pulsatile or reverberating pressure pulses contained within the muffler **14** of an exhaust system. Accordingly, vacuum chamber **62** comprises a large segmented, annular area extending around the outer periphery of baffle assembly **32**. Such vacuum enhances the velocity of exhaust gases that exit baffle assembly **32** which imparts enhanced evacuation of exhaust gases through muffler **14**. Accordingly, an engine that is coupled to such an exhaust system containing muffler **14** will see an increase in operating efficiency and performance.

Accordingly, as depicted in FIG. **5**, a pair of low, or negative (relative to atmospheric pressure), pressure regions are generated by vacuum chambers **56** and **62**. Cooperation of such vacuum chambers with adjacent high-velocity gases which exit compression chambers **52** and **58**, respectively, imparts further evacuation of such gases and dampens out any reverse pressure pulses which might otherwise travel upstream of an exhaust system. For example, it is known in the art that an improperly tuned exhaust system might produce positive pressure pulses that reverberate upstream of an exhaust system. If a positive pressure pulse is located within an engine manifold when an exhaust valve is opened, such occurrence can cause negative, unwanted back flow into an engine. Accordingly, it is desirable to evacuate such exhaust gases and prevent such reverse pressure pulses from traveling upstream of an exhaust system. It is presently understood that the provision of vacuum chambers **56** and **62** significantly dampens and reduces the occurrence of positive pressure pulses traveling upstream through muffler **14**. Accordingly, the tendency for unsteady state pressure pulses to reverberate within an exhaust system is significantly diminished and dampened.

The muffler embodiment illustrated in FIGS. **1–5** was tested on the exhaust system of a Vortech 350-cubic inch V8 engine, having an automatic transmission, and configured in a 1996 Chevrolet 1,500 4×4 pickup. A model No. 4L60E transmission and a 373 gear ratio were used. The test vehicle was run on a Bear chassis dynamometer Model No. 1132 in second gear. Measurements were made at 2,500, 3,000, 3,500 and 4,000 revolutions per minute (RPM) to determine the foot pounds of torque generated with such muffler. Additionally, a production Flowmaster muffler (part No. 43050) was compared with the stock (OEM) muffler (GM part No. 312548) provided on the 1996 Chevrolet 4×4 pickup, and with a Walker Superturbo Dynamax (part No. 17793). According to such results, the muffler embodiment depicted in FIGS. **1–5** generated 410 foot pounds of torque at 2,500 RPM, 390 foot pounds of torque at 3,000, 380 foot pounds of torque at 3,500 RPM, and 360 foot pounds of torque at 4,000 RPM. In comparison, the Flowmaster muffler generated 385 foot pounds of torque at 2,500 RPM, 390 foot pounds of torque at 3,000 RPM, 345 foot pounds of torque at 3,500 RPM, and 330 foot pounds of torque at 4,000 RPM. For further comparison, the OEM muffler generated 365 foot pounds of torque at 2,500 RPM, 370 foot pounds of torque at 3,000 RPM, 335 foot pounds of torque at 3,500 RPM, and 275 foot pounds of torque at 4,000 RPM. The Walker Superturbo Dynamax generated 375 foot pounds of torque at 2,500 RPM, 365 foot pounds of torque at 3,000 RPM, 340 foot pounds of torque at 3,500 RPM, and 310 foot pounds of torque at 4,000 RPM.

Additionally, exhaust gas temperatures were measured at the muffler. The muffler embodiment depicted in FIGS. **1–5** generated exhaust temperatures at the muffler of 730° F. The Flowmaster, OEM and Walker Superturbo Dynamax mufflers each generated exhaust temperatures in excess of 888° F.

In FIG. **6**, an alternative embodiment muffler **114** is illustrated having an elongate housing **120** constructed similarly to housing **20** (of FIG. **2**), but configured to be twice the length of housing **20**. Housing **120** contains two pairs of baffle assemblies **30** and **32**, provided in a serial arrangement. Accordingly, the operating principles described above with respect to FIGS. **2–5** are repeated twice within housing **120** as exhaust gases flow from inlet duct **22**, through muffler **114**, and through outlet duct **24**. In the process, exhaust gas travels from inlet duct **22**, around an upstream one of baffle assemblies **30**, through an upstream one of baffle assemblies **32**, around a downstream one of baffle assemblies **30**, through a downstream one of baffle assemblies **32**, and through outlet duct **24**. It is understood that the compression, expansion and vacuum chamber characteristics described in detail with respect to FIGS. **4** and **5** also occur between each pair of baffle assemblies **30** and **32**, contained within muffler **114**. Accordingly, the operating characteristics of the embodiment depicted in FIGS. **1–5** are carried out twice within muffler **114**, in a serial configuration.

As shown in FIG. **6**, housing **120** includes tubular member **125**, conical end caps **26** and **28**, and inlet ducts **22** and **24**, which are each formed from a piece of aluminized mild steel, similar to the construction described with reference to FIGS. **2–4**. Likewise, baffle assemblies **30** and **32** are contained within housing **120** according to the construction details that were described with reference to FIG. **4**.

The embodiment depicted in FIG. **6** enables further noise reduction of exhaust gases traveling through such muffler by carrying out the compression, expansion and dampening features depicted in FIG. **5** twice within the same muffler. Hence, additional sound attenuation is provided, additional pressure pulse dampening is provided, and additional enhancement of exhaust gas extraction is further provided according to such construction.

Another alternative embodiment is depicted in FIGS. **7** and **10–11** wherein additional sound-absorbing features are provided within a muffler **214**. According to the construction depicted in FIG. **7**, muffler **214** includes housing **20**, which is constructed substantially identically with housing **20** depicted in FIG. **4**. More specifically, housing **20** includes a tubular body **25**, an end cap **26** and **28**, and a respective duct **22** and **24**, provided at each end, respectively. Additionally, a first baffle assembly **130** is provided upstream of a second baffle assembly **132**. Baffle assembly **130** is constructed in a substantially similar manner to baffle **30** (of FIG. **4**). However, the additional feature of sound-deadening material **64** is provided within vacuum chamber **56**, and a perforated and concave cylindrical end plate **66** is used to encase such sound-deadening material **64** within vacuum chamber **56**.

Concave end plate **66** is affixed at a downstream end of conical baffle **34** via a circumferential weld. End plate **66** is formed from a piece of 16-gauge aluminized mild steel containing a plurality of 3⁄16"-diameter perforations **68** spaced apart in a pattern along plate **66**. Perforations **68** cooperate with the concave geometry of end plate **66** to enable the drawing of a vacuum or pressure reduction within vacuum chamber **56** via passage of accelerated exhaust gases there adjacent. Additionally, sound-deadening material **64** enhances the sound deadening, particularly of high-frequency components present within the adjacent exhaust gases. Also provided in the embodiment depicted in FIG. **7**, sound-attenuating, or deadening, material **64** is provided within vacuum chamber **62**. More particularly, a cylindrical, concave and perforated ring-shaped end plate **70** is circumferentially welded to a downstream end of frustoconical baffle **40**, and along a radial outer edge with an inner surface of housing **20**. Ring-shaped and concave end plate **70** is formed from a piece of 3⁄16" aluminized mild steel, and perforations **68** comprise 3⁄16"-diameter holes formed within plate **70**. Perforations **68** comprise apertures that cooperate with the concave geometry of end plate **70** to reduce pressure within vacuum chamber **62**.

According to one implementation, sound-deadening material **64** comprises relatively coarse, wiry metal material such as metal shavings that are generated from a machining operation, such as waste product generated by a metal lathe when turning a cylindrical piece of aluminized mild steel. One such configuration for sound-deadening material generated from a lathe-turning operation provides curled chips of waste material configured with a thickness of approximately 10–12 gauge. Alternatively, such sound-deadening material, or sound-attenuating material, can be formed from a metal wool such as stainless steel wool, composite materials, fiberglass, ceramic, glass wool, rock wool, or any other suitable sound-absorbing material capable of resisting breakdown when subjected to high temperature environments as encountered within a muffler and exhaust system. Accordingly, sound-absorbing material **64** is packed into vacuum chambers **56** and **62** where it is encased between the associated conical baffle **34** and end plate **66**, or frustoconical baffle **40** and ring-shaped end plate **70**, respectively.

In FIGS. **10** and **11**, further construction details are provided for the alternative embodiment depicted in FIG. **7**. More particularly, FIG. **10** is a vertical cross-sectional view taken along line **10**—**10** of FIG. **7** illustrating the downstream end of baffle assembly **130**. Likewise, FIG. **11** is a cross-sectional view taken along line **11**—**11** of FIG. **7** and illustrating the downstream end of baffle assembly **132**.

Baffle assembly **130** is depicted in FIG. **10** in partial breakaway view so as to enable visualization of sound-absorbing material **64** which is contained within vacuum chamber **56**, and behind perforated, concave end plate **66**. Additionally, the arrangement of individual perforations **68** can be readily visualized. Exhaust gases are accelerated by baffle assembly **130** such that a vacuum is generated via concave end plate **66** and through apertures **68** inside of vacuum chamber **56**. Accordingly, a low pressure region is generated within vacuum chamber **56** which aids in drawing exhaust gases through muffler **214**.

As shown in FIG. **11**, a downstream end view of baffle assembly **132** clearly illustrates the arrangement of perforated apertures **68** provided within ring-shaped end plate **70**. More particularly, exhaust gases are accelerated through compression chamber **58** where they exit downstream of baffle assembly **132**. Accordingly, the venturi effect generates a vacuum via apertures **68** inside vacuum chamber **62**.

In FIG. **12**, yet another alternative embodiment is depicted wherein housing **20** is formed substantially identical to the embodiment of FIGS. **1–5**, but wherein baffle assembly **230** (see FIG. **12**) and baffle assembly **232** (see FIG. **13**) are configured to have a plurality of support fins **136–138** and **142–144**, respectively, that are formed in a helical configuration. Such helical configuration is operative to impart rotation of exhaust gases flowing there along.

According to the construction depicted in FIG. **12**, fins **136–138** are each formed from a piece of 16-gauge aluminized mild steel that is roll-formed to impart a helical geometry extending along conical baffle **34**. Exhaust gases are delivered to impinge on conical baffle **34** where such gases are compressed between baffle **34** and an inner surface of housing **20**, and further imparted with rotation by the helical surfaces presented by fins **136–138**.

FIG. **13** illustrates an alternatively constructed baffle assembly **232** that can be provided in conjunction with the baffle assembly **230** of FIG. **10**. More particularly, fins **142–144** are roll-formed so as to impart a helical configuration, similar to that imparted to fins **136–138** (of FIG. **12**). Optionally, fins **142–144** can be stamped via a press to obtain the desired helical configuration. Fins **142–144** serve to support baffle assembly **232** from the radial inner surface of housing **20**. Additionally, the helical configuration imparted by baffles **142–144** further cooperates to impart swirling of gases as they are ejected from frustoconical baffle **40**, wherein a venturi effect applies vacuum which is at least partially affected by swirling induced via fins **142–144**.

In compliance with the statute, the invention has been described in language more or less specific as to structural and methodical features. It is to be understood, however, that the invention is not limited to the specific features shown and described, since the means herein disclosed comprise preferred forms of putting the invention into effect. The invention is, therefore, claimed in any of its forms or modifications within the proper scope of the appended claims appropriately interpreted in accordance with the doctrine of equivalents.

I claim:

1. A muffler, comprising:

an outer casing having an elongate configuration, a hollow interior, an inlet end, and an outlet end;

end caps mounted one at the inlet end and the other at the outlet end of the outer casing;

entrance and exit ducts connected to and communicating respectively with the end caps at the inlet end and the outlet end of the outer casing;

a plurality of flow-directing fins carried by the outer casing and extending within the hollow interior:

a conical diverging flow deflector supported coaxially within the hollow interior of the outer casing by at least two of the flow-directing fins, adjacent the entrance duct; and

a funnel-shaped converging flow deflector supported coaxially within the hollow interior of the outer casing, downstream of the conical deflector;

the conical deflector forming a conical vacuum chamber, and the funnel-shaped deflector cooperating with the casing to form an annular-shaped vacuum chamber.

2. The muffler according to claim **1** wherein the conical flow deflector comprises a conical baffle supported downstream of the entrance duct and within the outer casing.

3. The muffler according to claim **2** wherein the conical flow deflector further comprises a plurality of equally spaced-apart and radially outwardly extending support fins configured to support the conical baffle coaxially within the hollow interior of the outer casing.

4. The muffler according to claim **1** wherein the funnel-shaped flow deflector comprises a frustoconical baffle supported downstream of the conical flow deflector and upstream of the exit duct.

5. The muffler according to claim **4** wherein the funnel-shaped flow deflector further comprises a plurality of equally spaced-apart and radially outwardly extending fins configured to support the frustoconical baffle coaxially within the hollow interior of the outer casing.

6. The muffler according to claim **1** wherein the outer casing comprises an elongate tubular body.

7. The muffler according to claim **6** wherein the end caps each comprise a frustoconically shaped end cap affixed to either end of the elongate tubular body.

8. The muffler according to claim **1** wherein the outer casing, end caps, and entrance and exit ducts cooperate to form an elongate cylindrical housing.

9. The muffler according to claim **1** further comprising a concave and perforated end plate affixed to a downstream end of the conical flow deflector, the concave and perforated end plate cooperating with the conical flow deflector so as to define the conical vacuum chamber.

10. The muffler according to claim **1** further comprising a concave and perforated ring-shaped end plate secured to a downstream end of the funnel-shaped flow deflector and cooperating with the funnel-shaped flow deflector so as to define the annular-shaped vacuum chamber.

11. A method for conditioning exhaust of an internal combustion engine, comprising:

delivering exhaust gases from an internal combustion engine into a muffler housing containing a hollow interior;

compressing, guiding and accelerating the exhaust gases within the housing by passing the exhaust gases through a generally outwardly extending compression chamber having flow-directing fins;

dampening pressure variations within the exhaust gases by delivering the compressed exhaust gases adjacent a low pressure chamber;

compressing and accelerating the exhaust gases within the housing by diverting the exhaust gases in a generally inwardly extending direction within a compression chamber; and

removing the exhaust gases from the housing.

12. A method according to claim **11** further comprising the step of dampening pressure pulse variations within the exhaust gases following delivering the exhaust gases in a generally inwardly extending compression chamber by associating the compressed exhaust gases with a second low pressure chamber prior to evacuating the exhaust gases from the housing.

13. An exhaust conditioning device, comprising:

a housing having an entrance duct, an exit duct, and a hollow interior defined within the housing between the entrance duct and the exit duct;

a conical baffle carried within the housing downstream of the entrance duct and configured to form a generally outwardly extending compression chamber therebetween, the conical baffle cooperating with the housing to form a first vacuum chamber;

a frustoconical baffle carried within the housing downstream of the conical baffle and upstream of the exit duct and configured to form a generally inwardly extending compression chamber, the frustoconical baffle cooperating with the housing to form a second vacuum chamber; and

a perforated end plate affixed to a downstream end of one of the conical baffle and the frustoconical baffle so as to at least in part define the respective first vacuum chamber or second vacuum chamber.

14. The exhaust conditioning device of claim **13** wherein the perforated end plate is affixed to a downstream end of the conical baffle, the conical baffle and the perforated end plate cooperating so as to define a conical vacuum chamber therebetween.

15. The exhaust conditioning device of claim **14** further comprising sound-absorbing material interposed between the conical baffle and the perforated end plate.

16. The exhaust conditioning device of claim **13** wherein the end plate comprises a concave and perforated end plate affixed to a downstream end of the conical baffle, the concave and perforated end plate cooperating with the conical baffle to form the first vacuum chamber, wherein the first vacuum chamber comprises a conical vacuum chamber.

17. The exhaust conditioning device of claim **13** wherein the end plate comprises a perforated ring-shaped end plate carried at a downstream end of the frustoconical baffle, the frustoconical baffle, housing and ring-shaped end plate cooperating to form the second vacuum chamber, wherein the second vacuum chamber comprises an annular vacuum chamber.

18. The exhaust conditioning device of claim **17** further comprising sound-absorbing material interposed between the housing, the frustoconical baffle, and the ring-shaped end plate.

19. The exhaust conditioning device of claim **13** wherein the end plate comprises a concave and perforated ring-shaped end plate carried at a downstream end of the frustoconical baffle, and cooperating with the frustoconical baffle and the housing so as to define the second vacuum chamber, wherein the second vacuum chamber comprises an annular-shaped vacuum chamber.

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